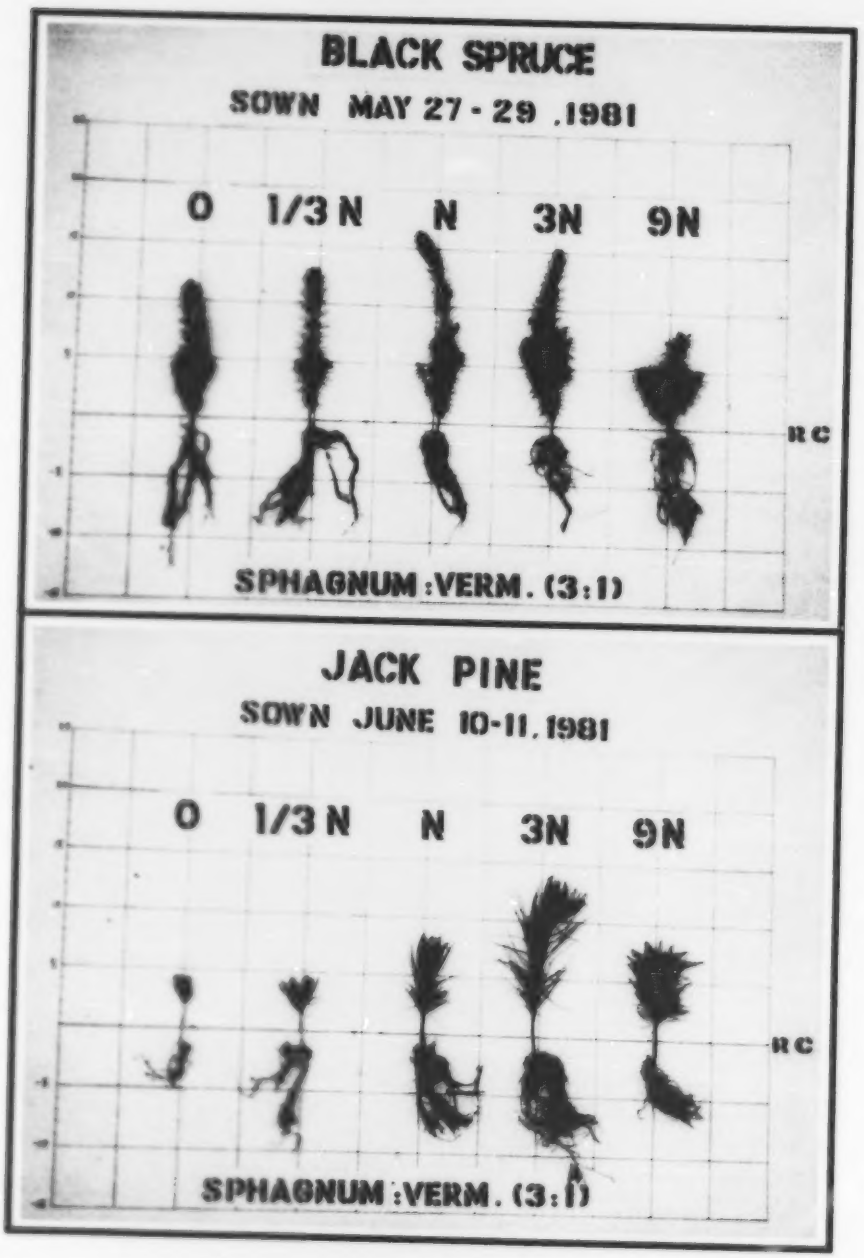
Forest Research Report No. 116

Response of Containerized Black Spruce and Jack Pine Seedlings to Fertilization Rate and Growing Medium



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Cover Photographs:

Representative black spruce (top) and jack pine (bottom) seedlings grown in a commercial sphagnum peat moss mixed in a 3:1 ratio with vermiculite at five rates of fertilization (N, "normal" operational rate of fertilization; O, non-fertilized; 1/3N, 3N and 9N are X operational fertilization rates). Photographed October 21, 1981.

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Response of Containerized Black Spruce and Jack Pine Seedlings to Fertilization Rate and Growing Medium

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Abstract

Black spruce and jack pine seedlings were grown at the Swastika Tree Nursery according to operational greenhouse practices, at 0, 1/3, 1, 3 or 9X the then operational fertilization rates for each species in three growing media (a local peat moss alone or in a 2:1 mixture with vermiculite, or a commercial peat moss in a 3:1 mixture with vermiculite). Black spruce seedlings were largest when grown in the commercial sphagnum moss with vermiculite (CP/V), at that species' operational (1X) rate of fertilization, equivalent to a total application of 11.35 mg N/seedling, 12.91 mg P/seedling and 9.38 mg K/seedling. Jack pine seedlings were also largest when grown in CP/V, but at 3X that species' operational rate of fertilization, equivalent to a total application of 9.19 mg N/seedling, 2.96 mg P/seedling and 5.6 mg K/seedling. Fall freezing damage and bud size in black spruce increased with fertilization up to the 3X rate. Bud size in jack pine also increased up to the 3X rate of fertilization, but there was no freezing damage.

Introduction

Despite the presence of handbooks for the production of containerized tree seedlings (Carlson 1979, Tinus and McDonald 1979), the determination of appropriate rates of fertilization remains an inexact science, since the rate and timing of fertilization can be affected by factors such as local variation in water chemistry, growing media and the environment in each greenhouse (Tinus and McDonald 1979).

The purpose of this report is to present the results of a semi-operational trial of fertilizer rates and growing media to assess for black spruce and jack pine container seedlings: (1) the range of fertilizer concentrations and seedling nutrient contents resulting in best seedling growth, and (2) the effect of fertilization on bud development and fall freezing damage.

Materials and Methods

The experiment was conducted under operational conditions at the Ontario Ministry of Natural Resources Provincial Tree Nursery at Swastika (Lat. N. 48°06', Long. W. 80°06'). On May 27-29 and June 10-11, 1981, respectively, black spruce (Picea mariana (Mill.) B.S.P.) and jack pine (Pinus banksiana Lamb.) seeds of northeastern Ontario seed sources were sown in containers filled with one of three growing media: i/ local "Dunmore" peat only (LP), ii/ local peat with vermiculite in a 2:1 mix by volume (LP/V), and iii/ a commercial sphagnum moss (Toubex[2]) with vermiculite (3:1) (CP/V). The local peat had a finer texture, higher cation exchange capacity, and was poorly drained in comparison to Toubex. The containers used were Japanese paperpots[2], FH308 for jack pine and FH408 for black spruce. The seedlings were grown in a quonset-type polyethylene-covered greenhouse under natural daylengths, and were moved outside during the last week in August.

Five rates of fertilization were tested in combination with each of the 3 growing media: in addition to the control treatment which received water only, fertilizer was applied at the then current operational rates for each species, shown in Table 1, or at 1/3, 3 or 9X those rates. Plant Products[1] 20-20-20, 28-14-14 or 10-52-10 soluble fertilizers were used at different stages of the growing schedule based upon operational procedures developed at the Swastika Tree Nursery, with first fertilizer application coinciding with the start of primary needle formation. An intermittent watering schedule was used, in which fertilizer was applied at high concentrations in small volumes of water. Between fertilizations, irrigation water was applied as needed in a quantity sufficient to prevent excessive drying but without leaching fertilizer from the growing medium.

Experimental Design and Analysis

For each species, a separate split-plot experimental design was used, consisting of a total of 9 paperpot trays - 3 trays (replicates) of each growing medium (LP, LP/V, CP/V). Each tray was divided into 5 subplots of approximately 67 seedlings in 408 paperpots or 105 seedlings in 308 paperpots. Each subplot received a different fertilizer treatment.

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[2] Mention of trade names does not indicate product endorsement.

TABLE 1 Schedule of operational fertilization rates used for jack pine and black spruce container seedlings.

Species	Fertilizer application schedule		Fertilizer formulation		Total nutrient application for period (mg/tree)		
	Consecutive periods	Frequency during period					
	(days)		N-P-K ratio	ppm N	N	P	K
Jack pine	15	3[a]	20-20-20	400	1.66[b]	0.72	1.38
	6	2	20-20-20	400	1.00	0.44	0.83
	10	2	28-14-14	600	4.88	1.07	2.02
		1	LEACH	0	0	0	0
	15	3	20-20-20	400	1.66	0.72	1.38
	Total Application (mg/tree)				9.19	2.96	5.61
Black spruce	15	3	10-52-10	300	2.15	4.91	1.78
	12	2	20-20-20	400	3.45	1.51	2.86
	10	2	20-20-20	500	3.59	1.58	2.96
		1	LEACH	0	0	0	0
	15	3	10-52-10	300	2.15	4.91	1.78
	Total Application (mg/tree)				11.35	12.91	9.38

[a] Application schedule is read as follows: for this example, the fertilizer formulation was applied every third day over a 15 day period (i.e. 5 applications).

[b] In the example from footnote (a) above, a total of 1.66 mg N was applied per tree in the 5 applications of 20-20-20 at 400 ppm N.

Seedlings were sampled in October to determine morphology (60 seedlings-20 per replicate, measured to determine shoot length, root collar diameter and root and shoot dry weights) and nutrient status (15 shoots-5 per replicate bulked for analysis of N, P, K, Ca and Mg). Seedlings on the borders of subplots were not sampled to avoid edge effects. Significant differences between treatments in each morphological parameter were determined using the least significant difference (LSD) test (5% level) following a split-plot analysis of variance.

In early April of 1982 following overwintering, 33 black spruce seedlings per treatment (11 seedlings per replicate) were examined for frost damage (presence of red needles), and their terminal buds were dissected to count the number of needle primordia. Jack pine suffered no frost damage. Thirty three jack pine seedlings per treatment (11 per replicate) were sampled for bud development. In this case, bud development was determined by counting the number of stem units (axillary buds in the rosette and budscales in the terminal bud) (Colombo 1982). Significant differences in bud development between treatments were identified using Tukey's test (5% level) following analysis of variance.

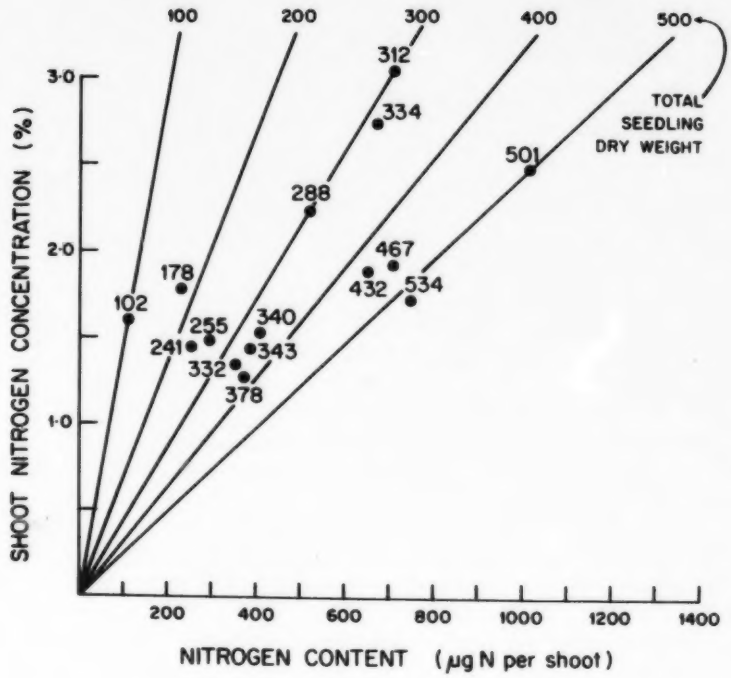

Figure 1 Graphical method of representation of the relationships between shoot nutrient concentration (% of dry weight), nutrient content (µg per seedling shoot) and seedling oven dry weight (g). Shown for black spruce seedlings. Numbers associated with points are total oven-dry weights for particular fertilizer growing media treatments.

The effect of fertilization was determined in two ways: (1) by plotting seedling dry weight versus fertilizer concentration, and (2) using vector analysis, studying the relationships among shoot dry weight, shoot nitrogen concentration (as a percent of shoot dry weight) and shoot nitrogen content (mg per shoot), following the procedure and interpretations of Timmer (Timmer and Stone 1978, Timmer and Armstrong 1987). As shown in Figure 1 for black spruce, shoot nitrogen content and percent nitrogen concentration formed the x- and y-axes of the graph respectively. One point was plotted for each of the 15 fertilizer rate-growing media treatments, using the 3 dimensions of seedling dry weight (shown for each plotted point in Figure 1), shoot nutrient concentration and shoot nutrient content. After these points were plotted, "isolines" of seedling dry weight were drawn on the graph. Isolines were drawn through the origin, using as guides for the slopes of the lines the dry weights shown for the plotted points. Following construction of the "isogram" the dry weight-nutrient concentration-nutrient content points were replotted separately for each growing medium, as shown in Figures 2 and 5. The response to increasing fertilizer rates were then interpreted using the following criteria: 1/ Dilution - seedling size and nitrogen content increasing, nitrogen concentration decreasing, 2/ Growth Response - size and nitrogen content increasing, concentration not decreasing, 3/ Luxury Consumption - nitrogen content and concentration increasing with no increase in seedling size, and 4/ Toxicity - decreasing seedling size with increasing nitrogen concentration.

Results

Black Spruce

The growing regime resulting in greatest size for black spruce was CP/V at the then operational rate of fertilizer application (Table 2). Seedlings in this treatment had the greatest height, root collar diameter and shoot and root dry weight compared with all other growing media and fertilizer rates. Seedlings grown in CP/V produced taller seedlings than in LP or LP/V at all but the 9X fertilizer application rate. The response of seedling height to fertilization rate by seedlings grown in CP/V was somewhat different than for seedlings grown in LP or LP/V: in CP/V, the non-fertilized control seedlings did not differ significantly in height from those receiving one third the recommended rate, whereas non-fertilized seedlings grown in LP and LP/V were significantly or just less than significantly shorter than at the 1/3X rate. Shoot/root ratio increased with fertilizer application in all growing media up to the 1X or 3X rate, but declined at the 9X rate.

Figures 2a-c show the vector analyses for black spruce seedlings in LP, LP/V and CP/V growing media respectively. In all cases, a toxic response occurred between 3X and 9X the operational level of fertilizer application. Using the graph of seedling dry weight versus fertilization rate (Fig. 3),

TABLE 2 Size and freezing damage of black spruce seedlings in three growing media at five fertilization rates.

Growing medium	Fertilization rate (X operational)	Height (cm)	Root collar diameter (mm)	Dry weight (mg)		Shoot/ root ratio	Freezing damage (% of seedlings)
				Shoot	Root		
LP	0	5.9	0.7	69	33	2.1	36.9
	1/3	10.4	1.0	179	62	2.9	11.4
	1	13.3	1.2	267	73	3.6	19.8
	3	14.2	1.4	370	97	3.5	49.0
	9	7.2	1.2	214	74	2.9	3.0
LP/V	0	7.4	0.9	133	45	2.7	11.1
	1/3	10.8	1.1	193	62	3.0	21.1
	1	13.3	1.2	268	75	3.6	47.2
	3	14.2	1.3	350	82	4.3	62.2
	9	8.4	1.3	247	87	2.8	8.6
CP/V	0	11.5	1.1	254	78	3.3	39.4
	1/3	13.0	1.2	292	86	3.4	43.7
	1	16.7	1.4	434	100	4.3	57.6
	3	15.1	1.4	410	91	4.5	48.1
	9	7.5	1.2	232	80	2.9	6.1
LSD (.05)[a]		3.57	0.28	136.0	26.0	1.25	20.02

[a] Means within columns separated by a difference less than the associated LSD (.05) value do not differ significantly.

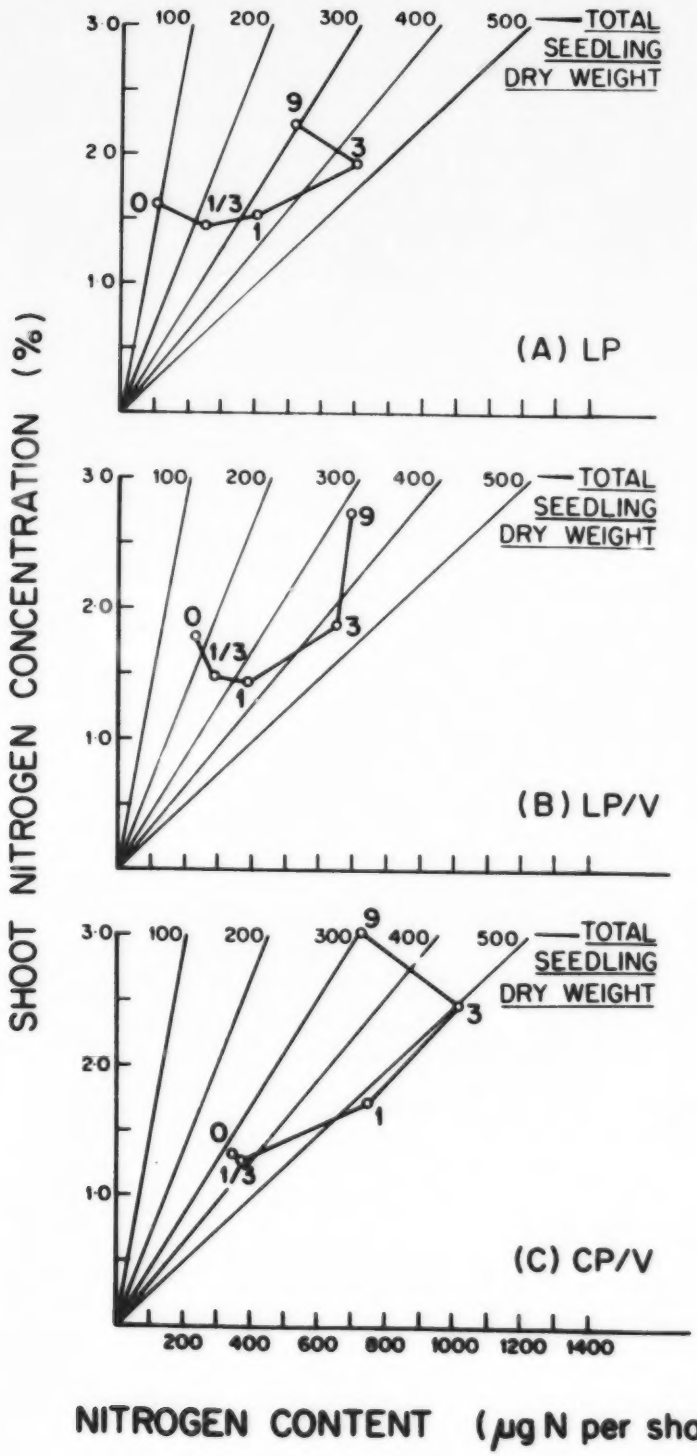

Figure 2 The relationships between shoot nitrogen concentration (mg N per g shoot dry weight), nitrogen content (µg N per seedling shoot) and seedling oven-dry weight (g) of black spruce container seedlings grown in a) LP, b) LP/V or c) CP/V growing media. Numbers associated with points are rates of fertilization.

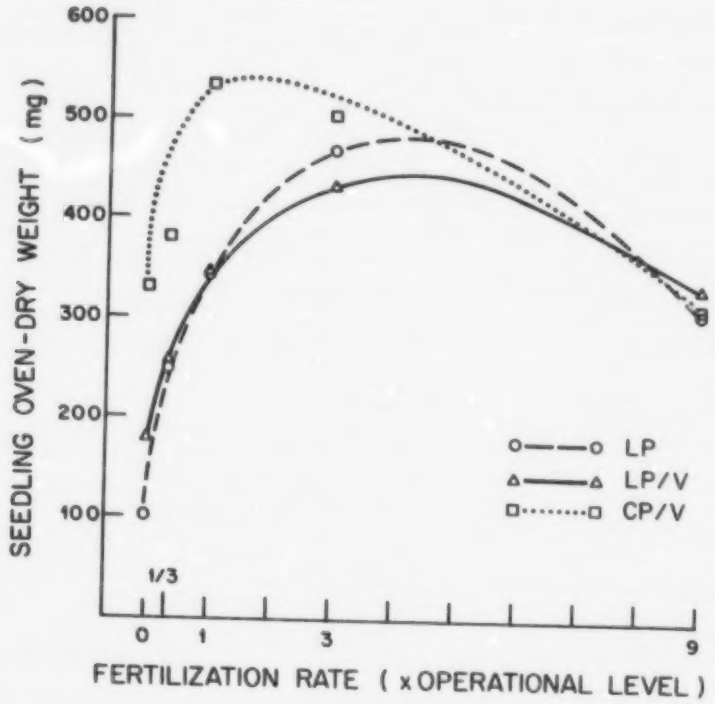

Figure 3 Effect of fertilization rate and growing medium on black spruce container seedling oven-dry weight in three media.

it is possible to determine that the optimum range of fertilization for LP and LP/V lay between 3X and 5X the operational rate, while for CP/V the optimum rate was between 1X to 2X the operational level.

Large differences in freezing damage to the shoots occurred, depending both upon growing medium and fertilization rate (Table 2). In LP and LP/V greatest damage occurred at the 3X fertilization rate (49 and 62% of the shoot tips damaged respectively), while for seedlings grown in CP/V damage was most severe (58%) at the operational rate of fertilization. In the non-fertilized controls, damage was 37 and 39% respectively in LP and CP/V, but was only 11% in LP/V. In all growing media, damage was less than 10% at the 9X fertilizer rate.

Seedlings fertilized at the 9X level formed the most needle primordia in all growing media (Fig. 4). At rates of fertilization less than 9X, only seedlings grown in LP and CP/V receiving the 3X level formed significantly more needle primordia than non-fertilized control seedlings. No significant differences in number of needle primordia occurred between media types at the same fertilization rate.

Jack Pine

Jack pine seedlings grown in CP/V at the 3X fertilizer rate were tallest and had the greatest root collar diameters and dry weights (Table 3). Seedlings in all media types responded similarly in height, root collar

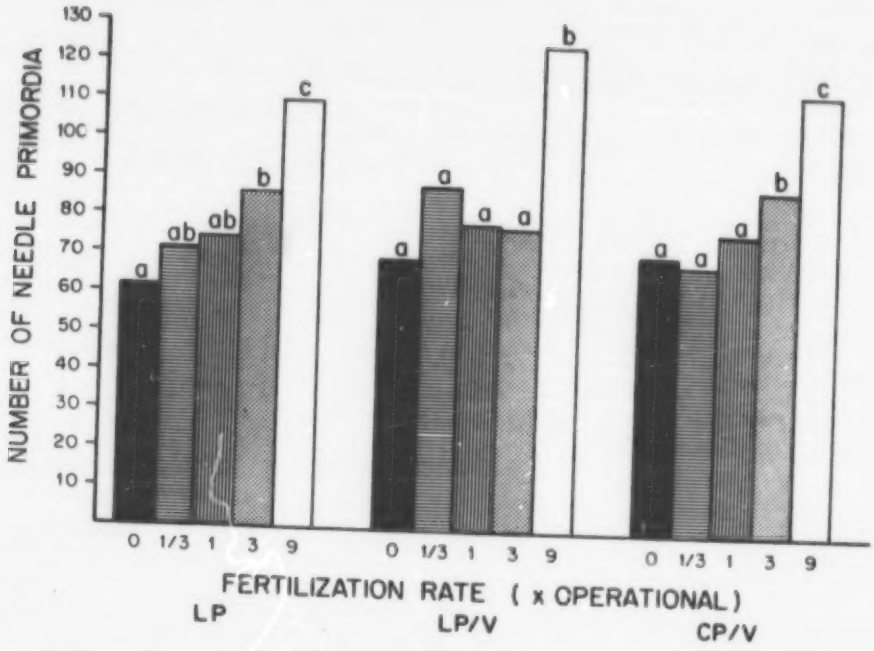

Figure 4 Effect of rate of fertilization and media type on the number of needle primordia in black spruce seedlings. Number of needle primordia within media types do not differ significantly according to Tukey's honestly significant difference (0.05 level) if associated by common letters. Fertilization levels are X the then operational rate.

TABLE 3 Size of jack pine seedlings in three growing media at five fertilization rates.

Growing medium	Fertilization rate (X operational)	Height (cm)	Root collar diameter (mm)	Dry weight (mg)		Shoot/root ratio
				Shoot	Root	
LP	0	4.1	0.7	49	43	1.1
	1/3	4.1	0.8	51	44	1.1
	1	6.5	1.0	109	70	1.6
	3	11.4	1.5	315	143	2.2
	9	9.7	1.5	300	144	2.1
LP/V	0	3.5	0.7	32	31	1.0
	1/3	4.0	0.8	52	45	1.2
	1	6.2	1.0	109	74	1.5
	3	11.5	1.5	330	150	2.2
	9	10.4	1.6	314	151	2.1
CP/V	0	4.0	0.8	47	40	1.2
	1/3	4.8	1.0	90	85	1.1
	1	8.0	1.2	175	113	1.6
	3	12.8	1.6	407	171	2.4
	9	8.9	1.4	248	107	2.3
LSD (0.05)[a]		2.18	0.27	102.5	55.6	0.54

[a] Means within columns separated by a difference less than the associated LSD (0.05) value do not differ significantly.

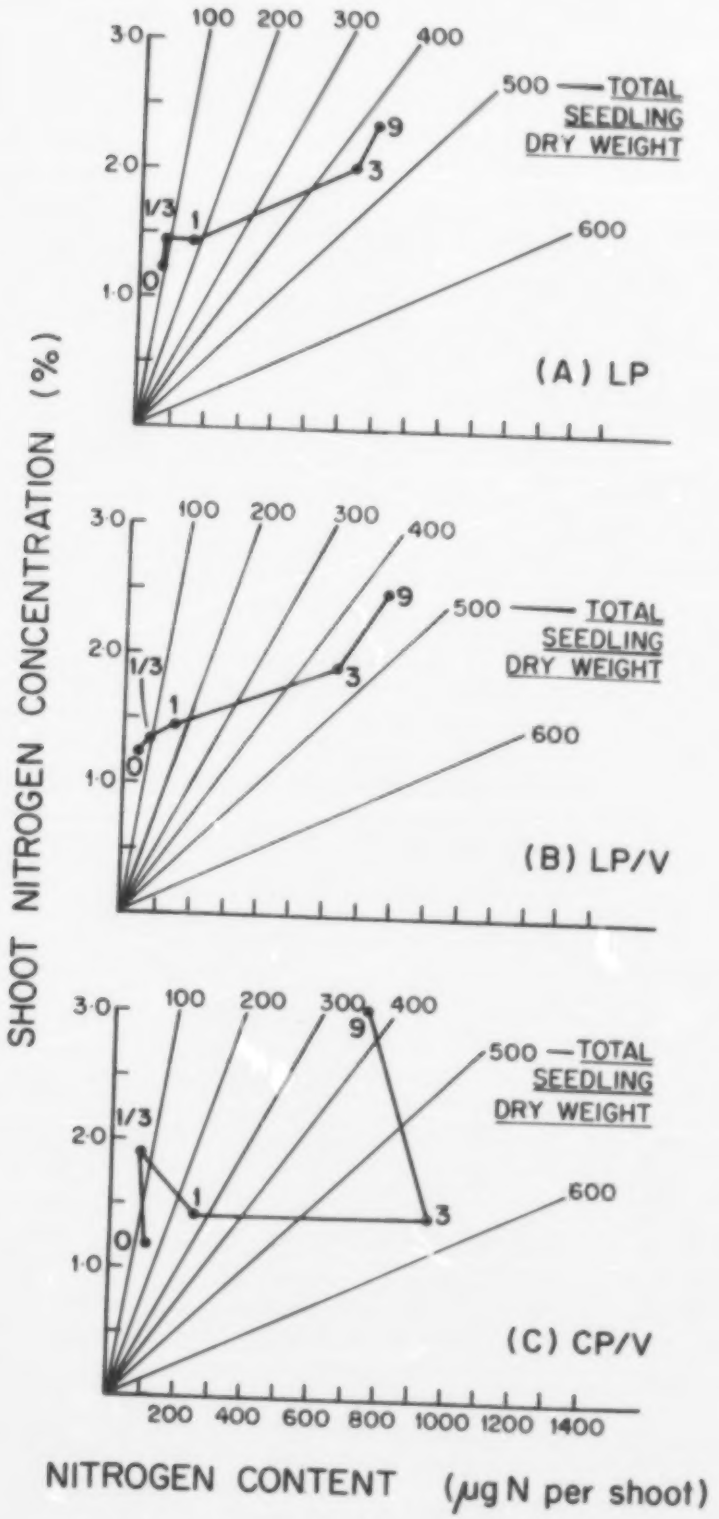

Figure 5 The relationship between shoot nitrogen concentration (mg N per g shoot dry weight), nitrogen content (µg N per seedling shoot), and seedling oven-dry weight (g) of jack pine container seedlings grown in a) LP, b) LP/V or c) CP/V growing media. Numbers associated with points are rates of fertilization.

seedling size increased with greater rates of fertilizer application to the 3X level, and decreased at the 9X level.

Isograms for jack pine are shown in Figure 5a-c respectively for seedlings in LP, LP/V and CP/V growing media. Growth responses occurred between 1 and 3X rates of fertilization in all growing media. In LP and LP/V there was luxury consumption between 3 and 9X rates of fertilization, while in contrast toxicity occurred in CP/V when seedlings were fertilized at the 9X rate. The graph of dry weight versus fertilizer rate (Fig. 6) shows that the optimal fertilizer rate would be 4X to 5X the operational level for seedlings grown in all growing media.

Fertilizer rate but not growing medium had a strong, positive effect on bud size of jack pine (bud size is made up of budscales plus axillary buds in the rosette, which composes the ensuing years predetermined shoot growth) (Fig. 7). On average, 20 to 30 stem units formed in non-fertilized seedlings and seedlings fertilized at the 1/3X rate. At the 1X rate, 54 stem units formed, while at the 3X and 9X fertilizer rates there were approximately 105 stem units.

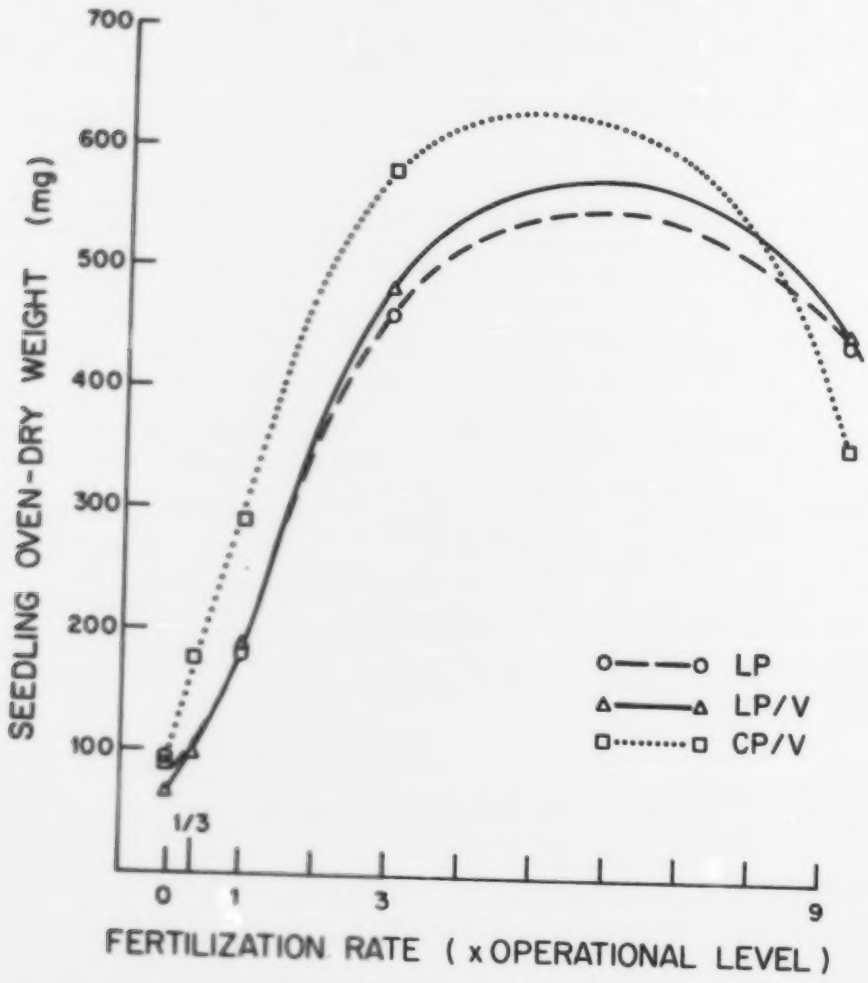

Figure 6 Effect of fertilization rate and growing medium on jack pine container seedling oven-dry weight in three media.

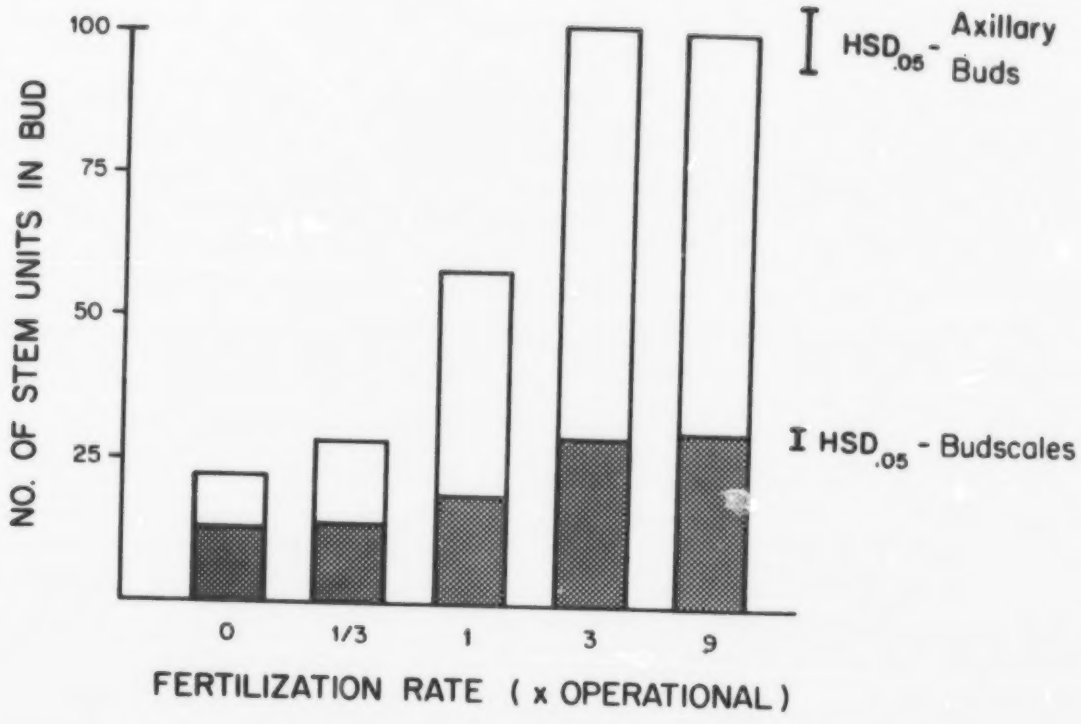

Figure 7 The number of stem units (axillary buds in the rosette and budscales in the terminal bud) of jack pine seedlings at various levels of fertilization. No significant differences occurred between media types at the same fertilization rate.

Discussion

The fertilizer rate resulting in greatest seedling growth of black spruce and jack pine containerized seedlings was dependent upon growing medium. The better growth of black spruce in CP/V than in LP or LP/V at levels of fertilization below the 3X level is attributed to the superior drainage and aeration characteristics of CP/V, the commercial peat moss plus vermiculite. Based on the results of this study, the use of local peat at the Swastika Tree Nursery was discontinued in favour of commercial sphagnum moss. However, local peat with properties similar to those of commercial brands could enable nursery managers to control the quality and supply of their growing medium more closely.

Of the two graphical methods for assessing the effects of fertilization rate on seedling growth, vector analysis allowed the identification of dilution effects, while the dry weight x fertilizer rate method allowed optimum concentration ranges to be identified. Using the seedling dry weight x fertilization rate method, optimum rates of fertilization for jack pine were estimated to be 4 to 5X the operational rate in all growing media. Optimum total nutrient application rates for jack pine are therefore estimated to be 37 to 46 mg N, 12 to 15 mg P and 22 to 28 mg K per seedling. For black spruce, optimum fertilization rates are predicted from Figure 3 to be lower in CP/V (1 to 2X the operational rate) than in LP and LP/V (3 to 5X the operational rate). In CP/V, therefore, optimum nutrient

application rates are estimated to be 11 to 23 mg N, 13 to 26 mg P and 9 to 19 mg K per seedling. In LP and LP/V, optimum rates are in the ranges 34 to 57 mg N, 39 to 64 mg P and 28 to 47 mg K per seedling. The extent to which these rates will vary from year-to-year in response to cultural conditions (e.g. watering practices, growing media, light and temperature) is unknown, although a longer growing period would obviously be expected to increase the optimum application rate. It remains to be confirmed whether these predicted optimum application rates will result in the expected growth response.

One of the potential uses of foliar nutrient concentration data is as a guide to fertilizer application schedules. For this to be feasible, test results must be able to be obtained quickly and nutrient concentrations resulting in optimal growth for a species should be relatively uniform between seedlings grown under different cultural conditions. In this trial, greatest growth (as judged by maximum dry weight accumulation) occurred at the foliar nutrient concentrations shown in Table 4. Foliar nutrient concentrations and contents for N, P, K, Ca and Mg for all growing media and fertilization rates are shown in Appendix A for black spruce and Appendix B for jack pine. For black spruce, N concentration associated with best growth ranged from 1.71 to 1.91% in different growing media, whereas for jack pine optimum N ranged from 1.91 to 2.33%. These nitrogen concentrations are comparable to those of Hallett (1982) for overwintered black spruce and jack pine seedlings, which suggests that optimum foliar N concentrations may be reasonably uniform between seedlings grown under quite different conditions. Concentrations of P, K, Ca and Mg associated with best growth were also similar between growing media within a species, with only one noteworthy exception (in jack pine grown in CP/V, the Ca concentration was less than half that of jack pine grown in LP and LP/V).

TABLE 4 Foliar nutrient concentrations associated with greatest total dry weight accumulation.

Growing medium	Fertilization rate (X operational)	Black spruce				
		N	P	K	Ca	Mg
Black spruce						
LP	3	1.91	0.28	1.06	0.53	0.09
LP/V	3	1.87	0.28	1.09	0.49	0.10
CP/V	1	1.71	0.29	1.10	0.46	0.12
Jack pine						
LP	3	2.04	0.24	1.00	0.54	0.11
LP/V	3	1.91	0.21	0.99	0.47	0.11
CP/V	3	2.33	0.24	1.01	0.23	0.13

Concentrations of P, K and Mg tended to be lower than other reported optima foliar nutrient concentrations for black spruce (Hallett 1982, Swan 1969). For jack pine in comparison, P, K and Mg concentrations resulting in optimal growth were similar to those reported by Ingestad (1960) and Swan (1969). Ca concentrations in either species generally exceeded reported optimum concentrations (Hallett 1982, Ingestad 1960, Swan 1969). This information contributes towards a database of acceptable foliar nutrient concentrations for container stock in Ontario. Data is also required on optimal foliar nutrient concentrations which occur during the rapid seedling growth phase, in case these differ from the values found in the present trial in which samples were collected following the completion of growth (Hallett 1982).

Bud development in jack pine was closely related to seedling diameter. Seedlings fertilized at the 3X or 9X rates had greater diameters (1.4-1.6 mm) than unfertilized and 1/3X seedlings (0.7-1.0 mm diameter), but the 3-9X seedlings had buds approximately four times greater in size. In black spruce similarly, seedlings in the fertilizer regimes up to the 3X rate resulting in greatest seedling diameter also had the greatest numbers of needle primordia. It may, therefore, be possible for nursery managers to increase black spruce and jack pine bud development by maximizing seedling diameter.

Freezing damage to black spruce generally increased with increasing fertilization rate up to the 3X level. We attribute this to early removal from the greenhouse for overwintering and a progressive delay in bud initiation due to increased seedling nitrogen content. The lack of freezing damage and superior bud development in black spruce at the 9X level was probably an indirect benefit of over-fertilization; high salt levels stressed seedlings and caused early bud initiation, allowing a longer period for frost hardiness and bud development before the seedlings would be exposed to potentially damaging freezing temperatures. Black spruce bud development was poor in all treatments, (ranging from 60 to less than 130 needle primordia), which we attribute to cold temperature hardening. Seedlings hardened under warm temperatures ordinarly produce buds containing between 200 and 300 primordia (Colombo and Odlum 1984).

In conclusion, nursery managers should adjust fertilizer rates depending on species and growing media. It is also important that nursery managers consider the effect of fertilization not only on growth, but also on frost hardiness and bud development.

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APPENDIX A. Black spruce container seedling shoot nutrient concentrations and contents.

Growing medium	Fertilization rate (X operational)	Shoot nutrient concentrations (% of oven dry weight)					Shoot nutrient contents (mg x 10^{-1} per seedling)				
		N	P	K	Ca	Mg	N	P	K	Ca	Mg
LP	0	1.61	0.24	1.08	0.78	0.10	111.1	16.6	74.5	53.8	6.9
	1/3	1.44	0.27	0.99	0.56	0.09	257.8	48.3	177.2	100.2	16.1
	1	1.53	0.27	1.04	0.55	0.09	408.5	72.1	277.7	146.9	24.0
	3	1.91	0.28	1.06	0.53	0.09	706.7	103.6	392.2	196.1	33.3
	9	2.45	0.31	1.11	0.53	0.07	524.3	66.3	237.5	113.4	15.0
LP/V	0	1.78	0.22	0.98	0.44	0.09	236.7	29.3	130.3	58.5	12.0
	1/3	1.48	0.25	1.01	0.44	0.09	285.6	48.3	194.9	84.9	17.4
	1	1.43	0.26	1.03	0.45	0.09	383.2	69.7	276.0	120.6	24.1
	3	1.87	0.28	1.09	0.49	0.10	654.5	98.0	381.5	171.5	35.0
	9	2.73	0.32	1.06	0.48	0.09	674.3	79.0	261.8	118.6	22.2
CP/V	0	1.33	0.23	0.92	0.34	0.09	337.8	58.4	233.7	86.4	22.9
	1/3	1.28	0.30	1.17	0.36	0.13	373.8	87.6	341.6	105.1	38.0
	1	1.71	0.29	1.10	0.46	0.12	742.1	125.9	477.4	199.6	52.1
	3	2.47	0.29	0.97	0.23	0.09	1,012.7	118.9	397.7	94.3	36.9
	9	3.04	0.35	1.03	0.21	0.08	705.3	81.2	239.0	48.7	18.6

APPENDIX B. Jack pine container seedling shoot nutrient concentrations and contents.

Growing medium	Fertilization rate (X operational)	Shoot nutrient concentrations (% of oven dry weight)					Shoot nutrient contents (mg x 10^{-1} per seedling)				
		N	P	K	Ca	Mg	N	P	K	Ca	Mg
LP	0	1.23	0.13	0.56	0.66	0.12	60.3	6.4	27.4	32.3	5.9
	1/3	1.45	0.16	0.66	0.54	0.12	74.0	8.2	33.7	28.6	5.6
	1	1.43	0.23	0.91	0.56	0.11	155.9	25.1	99.2	61.0	12.0
	3	2.04	0.24	1.00	0.54	0.11	642.6	75.6	315.0	170.1	34.7
	9	2.35	0.31	1.18	0.67	0.10	705.0	93.0	354.0	201.0	30.0
LP/V	0	1.23	0.09	0.48	0.68	0.13	39.4	2.9	15.4	21.8	4.2
	1/3	1.33	0.16	0.76	0.49	0.13	69.2	8.3	39.5	25.5	6.8
	1	1.46	0.21	0.91	0.41	0.11	159.1	22.9	99.2	44.7	12.0
	3	1.91	0.21	0.99	0.47	0.11	630.3	69.3	326.7	155.1	36.3
	9	2.48	0.28	1.15	0.69	0.10	778.7	87.9	361.1	216.7	31.4
CP/V	0	1.80	0.19	0.65	0.29	0.13	84.6	8.9	30.6	13.6	6.1
	1/3	1.18	0.17	0.74	0.23	0.14	106.2	15.3	66.6	20.7	12.6
	1	1.42	0.21	0.97	0.25	0.14	248.5	36.8	169.8	43.8	24.5
	3	2.33	0.24	1.01	0.23	0.13	948.3	97.7	411.1	93.6	52.9
	9	3.04	0.27	1.00	0.18	0.10	753.9	67.0	248.0	44.6	24.8